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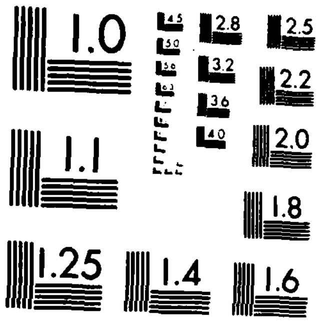


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US Army Corps of Engineers
Construction Engineering Research Laboratory

CERL

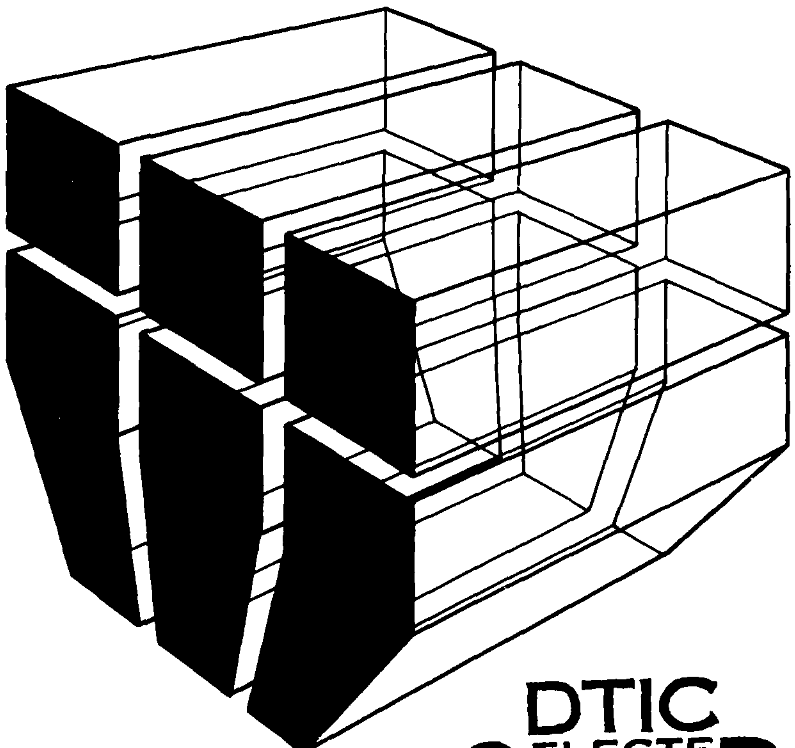
Interim Report E-187
January 1984

Installation Energy Conservation Strategy Program Development



# ENERGY CONSERVATION STRATEGIES FOR ARMY INSTALLATIONS

by
D. C. Hittle





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| REPORT DOCUMENTATION PAGE | | READ INSTRUCTIONS BEFORE COMPLETING FORM |
|---|---|---|
| 1. REPORT NUMBER CERL-~~TR~~ R-E-187 | 2. GOVT ACCESSION NO. AD-A137 918 | 3. RECIPIENT'S CATALOG NUMBER |
| 4. TITLE (and Subtitle) ENERGY CONSERVATION STRATEGIES FOR ARMY INSTALLATIONS | | 5. TYPE OF REPORT & PERIOD COVERED Final |
| | | 6. PERFORMING ORG. REPORT NUMBER |
| 7. AUTHOR(s) D. C. Hittle | | 8. CONTRACT OR GRANT NUMBER(s) |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. ARMY CONSTRUCTION ENGINEERING RESEARCH LABORATORY P.O. BOX 4005, CHAMPAIGN, IL 61820 | | 10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 4A762781AT45-B-001 |
| 11. CONTROLLING OFFICE NAME AND ADDRESS | | 12. REPORT DATE January 1984 |
| | | 13. NUMBER OF PAGES 28 |
| 14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) | | 15. SECURITY CLASS. (of this report) Unclassified |
| | | 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE |

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Copies are available from the National Techncial Information Service
Springfield, VA 22161

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

energy conservation
military requirements

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report summarizes research to (1) identify problems in current energy conservation programs and (2) identify the policies, programs, and research efforts needed to support and improve the effectiveness of these programs. The study described in this report evaluated the energy decision-making and energy management processes at the installation level and in scoped

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and organized problems associated with effective conservation and cost avoidance. The purpose of this study was to ensure that all problems were identified and organized. Finding solutions is a larger, ongoing and future effort.

To achieve the goals of this study, policy documents were reviewed, energy use data was analyzed, site visits were made, and an "ideal" energy conservation strategy was developed to facilitate problem identification and classification.

Major problems were identified, including: the need for more energy use and for procedures to effectively use energy data to control consumption; the need to determine the optimum level of energy-related management and maintenance; the need to collect and share energy conservation project data; and the need to simultaneously consider conservation programs, maintenance and repair, fuel selection, and centralized vs decentralized energy systems.

Potential solutions to the problems identified are suggested. Where applicable, research and development requirements and progress (if any) are also given.

## FOREWORD

This research was conducted for the Assistant Chief of Engineers, under Project 4A762781AT45, "Energy Conservation"; Task B, "Installation Energy Conservation Strategy"; Work Unit 001, "Installation Energy Conservation Strategy Program Development." The work was performed by the Energy Systems Division (ES) of the U.S. Army Construction Engineering Research Laboratory (CERL). The Technical Monitor was Mr. B. Wasserman, DAEN-ZCF-U. Dr. D. C. Hittle was the CERL Principal Investigator.

The special assistance provided by Mr. S. Mason, ATEN-FE-EN, Mr. J. Weigel, AFEN-TSC-R, and the Facilities Engineer and his staff at Fort Bragg is gratefully acknowledged. CERL also wishes to thank the participants in the In-Process Review for this project for their candid and thoughtful comments: LTC Robert Hutchenson, Bernie Wasserman, and Ed Zulkofske of OCE; Steve Mason and Dave Lyon of TRADOC; Don Fournier and James Thompson of FESA; Dwaine Nelson of Fort Knox; COL Alexander Johnston and Robert Wilkerson of Fort Campbell; Dexter Young of Fort Ord; Art Ragland of Fort Lee; Jerry Aveta of DARCOM; Jim Willis of Fort Benning; Dave Hale of Fort Belvoir; Guy Dunnavant of FORSCOM, and Steve Flanders of Cold Regions Research and Engineering Laboratory.

Mr. R. G. Donaghy is Chief of CERL-ES. COL Paul J. Theuer is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.

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ENERGY CONSERVATION STRATEGIES
FOR ARMY INSTALLATIONS

# 1 INTRODUCTION

## Background

Since 1973, the Army has been motivated to conserve energy on its installations because of rising fuel prices and the requirements of a number of executive directives and legislative mandates. The most recent summary of Army energy conservation programs is the Army Facilities Energy Plan.[1]

Money has been spent in two major areas of the Army's overall energy conservation program: (1) the Energy Engineering Analysis Program (EEAP) a program of engineering studies of military installations for defining energy conservation projects and developing energy master plans, and (2) the Department of Defense (DOD) Energy Conservation Investment Program (ECIP) and Energy Conservation and Management Program (ECAM) military construction programs for energy conservation retrofit projects. In addition, regulations and policy statements have made installation personnel more aware of energy conservation; an Energy Conservation Officer* with limited responsibility for conservation programs has been appointed at most installations.

Although much of the Army's decreased energy use since 1975 is due to reduced industrial production following the Vietnam War, energy use data shows that ECIP has provided significant fuel savings.[2] Much more energy can be saved by continuing these programs and starting new ones; however, as the easiest programs are completed, conservation will become increasingly more difficult.

The Army has succeeded in reducing its energy consumption compared to the baseline;[3] however, all military organizational elements (Facilities Engineers [FEs], Major Commands [MACOMs], OCE, and DOD) are continually trying to reduce energy consumption even more. Difficult questions are repeatedly raised when making energy conservation investment decisions: Are the "best" retrofit projects being funded first? Do Facility Engineers have enough data to determine where energy is being consumed on Army installations? Can Facility Engineers identify the energy conservation opportunities on their installations? Do retrofit projects produce the predicted energy savings? Are low cost/no cost conservation alternatives being overlooked? Are energy management, public awareness, and command emphasis programs effective? Are enough of the right

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[1] Army Facilities Energy Plan, revised draft (Department of the Army, Office of the Chief of Engineers, 26 October 1981).

*Energy Conservation Officer is an unofficial title which is not uniformly applied. It is used in the report to identify the single point of contact designated as responsible for installation energy matters. Establishing an Energy Management Office at each installation is now required by AR 11-27.

[2] Army Energy Data Analysis (Department of Energy, June 1981).

[3] Army Energy Data Analysis.

kind of resources being devoted to management of energy use on Army installations?

## Objective

The objectives of this project were to systematically examine energy conservation programs at Army installations in order to identify problems and constraints associated with current energy conservation efforts and to identify those problems which required or could benefit from additional research and development (R&D). These objectives support the development of a comprehensive research and development plan designed to improve the effectiveness of energy conservation programs.

## Approach

The following approach was used to accomplish the above objectives:

1. Existing policy documents were reviewed.

2. Measured building energy use and post-wide energy use data were analyzed for various installations and for the Army as a whole.

3. Selected FE personnel were interviewed informally, and experiences of CERL staff during other field visits were collected.

4. A detailed study of Fort Bragg was made which included:

   a. Collection of extensive building data via the Integrated Facilities System (IFS).

   b. Two visits to gather available data, inspect typical buildings, review tentative conservation projects, and interview FE staff.

5. Energy engineering analysis program studies were reviewed.

6. A model for an ideal building energy conservation and management program on an installation was developed, and the problems associated with implementing this model were identified.

7. An informal review of project results was conducted involving OCE and MACOM personnel.

8. An In-Process Review was conducted to solicit comment from OCE, MACOM, Army Energy Office, and FE personnel.

## Scope

Chapter 2 discusses the studies and analyses used as the basis for developing an "ideal" building energy conservation and management program.

Chapter 3 describes this "ideal" model which consists of three major elements: (1) data collection and analysis, (2) retrofit, and (3) management and maintenance.

Chapter 4 identifies the constraints that affect each step of the ideal strategy and hinder its application.

Chapter 5 provides data which show that the retrofit phase of the strategy for building energy conservation is cost-effective. The absence of data on the potential cost effectiveness of other phases of the strategy is discussed and field experiments are recommended.

Chapter 7 presents conclusions and recommendations in the form of Problem/Need statements. This report deals only with information about existing buildings and energy management on existing posts; energy conservation in the design of new buildings is considered in another report.[4]

## Mode of Technology Transfer

The results of this study are intended to provide guidance for further research and development program planning. This report reflects a consensus of the reviewers concerning the compelling need for R&D related to energy conservation. Appropriate R&D efforts will be included in the Army's energy-related Science and Technology plans. Interim recommendations for changes in policy or procedure may be implemented by OCE and other MACOMs through Engineer Technical Notes, Engineer Technical Letters, Engineering Improvement Recommendation System Bulletins, or other formal or informal directives.

[4] D. Leverenz, C. Lozar, A. Stumpf, and D. Herron, Energy Impact Analysis of the MCA Building Delivery System, Technical Report E-188 (U.S. Army Construction Engineering Research Laboratory [CERL]).

## 2 PROCEDURE

Existing energy conservation policy documents were reviewed to determine the type of guidance being provided to field operating agencies. Documents summarizing the effectiveness of Army conservation programs were also examined.

The two basic policy documents affecting the Army are (1) the Army Energy Plan (Department of the Army, August 1980) and (2) the Army Facilities Energy Plan (Office of the Chief of Engineers, October 1980). The first document summarizes Army energy use and sets conservation goals for all Army agencies. The second document discusses energy use at Army facilities and establishes goals for reducing energy consumption in buildings and other fixed facilities.

Energy consumption data are available in (1) Facilities Engineering Annual Summary of Operation, FY80 (Department of the Army, Office of the Chief of Engineers) and (2) Army Energy Data Analysis, FY80 Update (Computer Science Corporation, FESA-T-2108, U.S. Army Facilities Engineering Support Agency, Technical Support Division, Fort Belvoir, VA). The documents were reviewed to determine the extent to which goals were being achieved and to establish general Army-wide trends in energy conservation. Some of the data from the above reports was compared to data from the Defense Energy Information System; agreement was reasonably good ($\pm$ 10 percent).

Selected FE personnel were interviewed informally to determine the impact of energy conservation programs and energy conservation policy on their programs. These interviews determined the extent to which energy conservation policy guidance was being emphasized within the FE organizations and identified technical and administrative problems with energy conservation projects and programs. Additional background information was obtained from other energy-related field experiments and visits to Army installations.

Next, a detailed study of energy use was conducted at Fort Bragg to better characterize energy conservation efforts at the installation level. Extensive building data were collected through the Integrated Facilities System (IFS) computer system. It was used not only to determine what data were available and how complete the data were, but also to assess the system's usefulness in managing building data and potentially managing data related to building energy use.

During two visits to Fort Bragg, researchers gathered available data, inspected typical buildings, reviewed tentative conservation projects, and interviewed FE staff. The purpose of these visits was to reexamine first-hand, the energy conservation problems at the FE level. Specific tasks during the visits included: establishing what energy data were available at a typical installation; determining the condition of typical buildings and their energy systems; reviewing progress toward implementing energy conservation projects, including low cost/no cost energy conservation efforts; determining the extent of interaction between the FE staff and architect/engineers performing energy engineering analysis program studies; and determining the degree of command emphasis on energy conservation.

Six energy engineering analysis program studies were also reviewed to determine the types of ECIP projects being identified under EEAP and to assess the methods by which energy savings potential was being calculated for energy conservation projects.

These activities were the basis for developing a model for an ideal building energy conservation and management program at Army installations. This "common sense" model was developed to identify, classify, and discuss constraints associated with energy conservation programs.

Chapter 3 discusses the ideal energy conservation model, and Chapter 4 outlines problems and constraints associated with implementing such a strategy.

## 3 A MODEL FOR IMPLEMENTING ENERGY CONSERVATION

In 1980, 83 percent of the energy the Army consumed was for buildings and other fixed facilities. Therefore, a model was developed to show what an FE might do, under ideal circumstances, to conserve and manage energy consumption in buildings (see Figure 1). This model is a flowchart of a conservation and energy management program; it is intended to be a model for discussion and a focal point for identifying problems and research areas. It provides a convenient framework for presenting the results of the first five tasks outlined in the Approach section of Chapter 1, and is therefore presented first, even though its development was preceded by other tasks.

Each step in the model is described below. Each step is then considered again in terms of data availability and the possibility of accomplishing it effectively (see Chapter 4). Research areas are defined, and policy and program impacts are identified. For some steps, conflicts in policy or goals and potential bottlenecks are discussed in hopes that they may be resolved in the future. Broader issues, which are not limited to the conservation of energy in individual buildings, are also described (see Chapter 5).

### *Data Collection and Analysis*

The first step (labeled B1 in Figure 1) in an ideal energy conservation strategy model is to compile a list of buildings and other energy users. For each building and energy user in the list, there are two requirements. One (labeled B2) is to determine the expected building energy use; the other (labeled B3) is to determine the actual building energy use. A realistic number is intended for the expected energy use requirement. For example, building energy budgets, established for new buildings, are design budgets and may be unreasonably low or high estimates when the as-built state of the building and its real use patterns are considered. Expected building energy use means the number of British thermal units and/or kilowatt hours per month, year, or heating or cooling degree day that realistically can be expected to be consumed by a building that is operated prudently. It includes energy consumed by any "processes" housed in the building. The emphasis here is on realistic, rather than ideal building energy use expectations.

The next step is to compare a building's actual and expected energy use (step B4). This leads to step B5, a decision about whether the building is using more energy than expected. This decision leads to either a retrofit path or a management and maintenance path.

### *Management and Maintenance*

If actual energy use for a particular building is greater than expected, the next step (M1) is to inspect and audit the building. Then, another decision must be made (step M2); that is, is the building constructed and used as designed? If the answer is "no," the diagram of Figure 1 shows a path for revising the expected energy use (step M3); then the comparison of step B4 is repeated. If the building is using more energy than expected, and its construction and use (including process energy consumption) indicate that the original expected energy use figure was reasonable, then there is something wrong with the building or with how it is being used. Hence, the next step along the management and maintenance path (step M4) is to identify the reasons

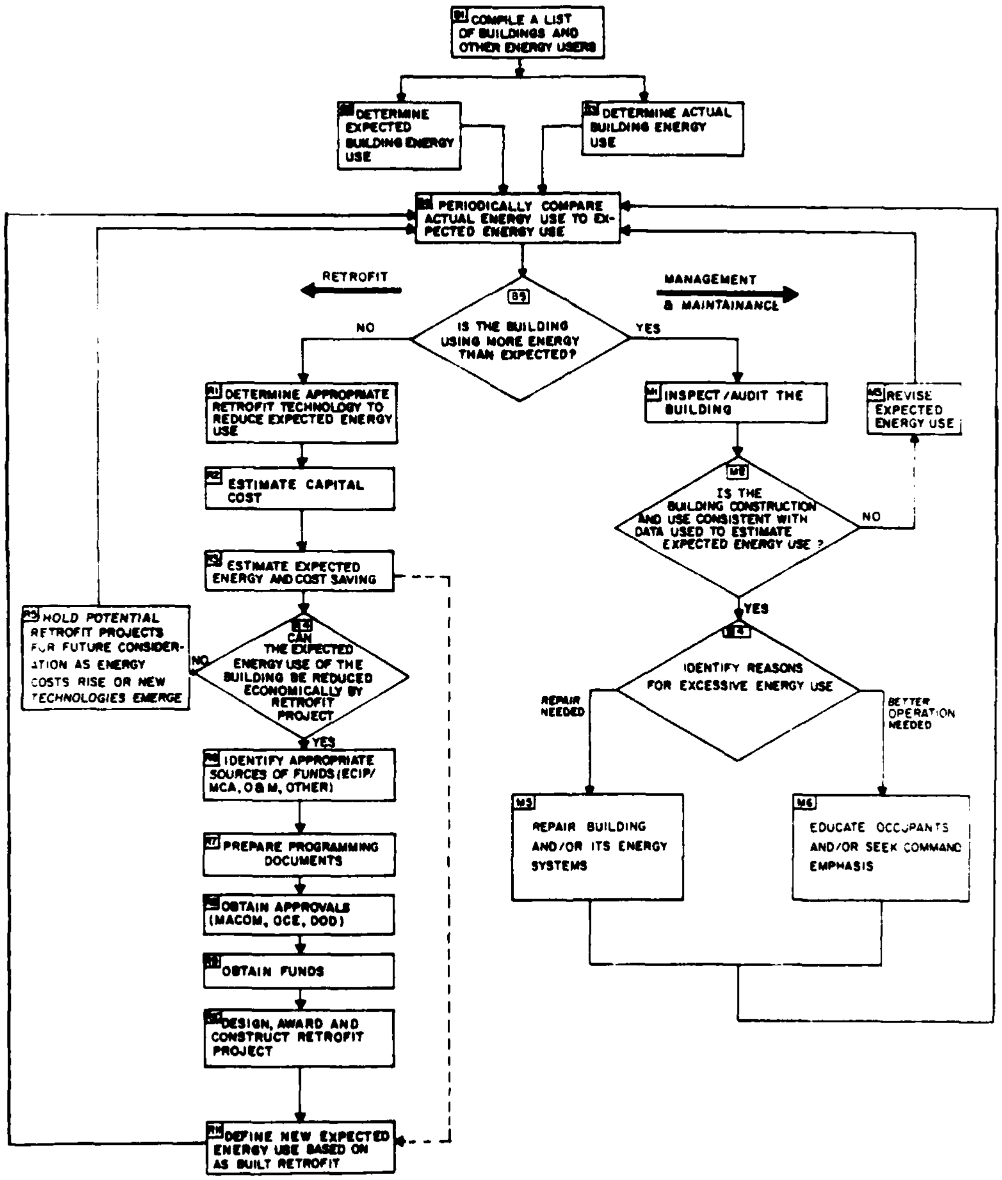


Figure 1. Energy conservation and management program flowchart.

or excessive energy use. There are two possible causes: a damaged building or process, or efficient use habits.

Repair of the building, the process, or its energy system (for example, repair control systems, stuck dampers, or p ,rly fitting windows) may be required. If inefficient use is the problem, the path leading to M6 is taken. Occupant education may be needed (for example, train building users to turn lights and heat off when they leave the building at night), or perhaps command emphasis is needed to motivate building users to conserve energy. Both branches of the energy management path return to step B4--the periodic comparison of actual with expected energy use.

*Retrofit*

Taking the retrofit path (that is, the path from Block B4 that the building is not using more energy than expected),* the next step (R1) is determining appropriate retrofit technology to reduce expected energy use. This step and the next two steps--estimating capital cost (R2) and estimating energy and cost savings (R3)--are the responsibility of the FE. Providing data to support the FE in carrying out these tasks has been the main emphasis of the Energy Engineering Analysis Program.

On the retrofit path, the ideal energy conservation strategy calls for deciding (step R4) whether a building's expected energy use can be reduced economically by a retrofit project. If the answer is yes, the next step (R6) requires identifying appropriate funding sources. While ECIP and ECAM have been emphasized, other MCA and OMA sources may also be appropriate. Next, projects for all buildings should be listed by priority and a management plan developed to complete them in the proper order.

After defining the appropriate funding source, program documents must be prepared (step R7). Next, program approvals (step R8) and funds (step R9) must be obtained.

The next step is designing, awarding, and constructing the project (step R10).

When the project is completed (step R11), new expected energy use figures should be computed. These figures should be nearly the same as the results from step R3 but should reflect changes which may have occurred between preliminary and final design. Also, when a retrofit project is completed, the proposed observation strategy requires that the actual energy use be compared to the new expected energy use to insure that the retrofit project has been effective (see Figure 1).

Returning to step R4 of the decision block, one sees that, if expected energy use cannot be reduced economically, a retrofit project is not practical. However, potential retrofit projects should be reevaluated periodically

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*To say that a building is not using more energy than is expected is not to say that it is not using more energy than it should. Retrofit projects can reduce the building's expected energy use and its actual energy consumption.

as energy costs rise or newer, less costly retrofit technologies become available (step R5).

Note that the overall energy conservation model always returns to step B4 (comparing expected with actual energy use). This makes step B4 pivotal and emphasizes that an effective energy conservation program involves constant scrutiny. Frequently reexamining each building in terms of its expected vs. actual energy use is particularly important since such comparisons form the basis for implementing effective O&M and retrofit programs.

The energy conservation strategy shown in Figure 1 portrays an ideal situation. If it were possible to use this process for each building and energy consumer, optimum (most cost-effective) energy use could be achieved. In addition, this strategy could form the basis for a detailed, easily defensible Installation Facilities Energy Plan. Furthermore, portions of the strategy could be adapted to assess the energy impact of major changes in the installation's mission or population.

Comparing the ideal strategy with actual programs allows us to identify problem areas and constraints. Chapter 4 addresses each step in the ideal process to determine whether an FE can accomplish it effectively and to note specific problems and constraints.

# 4 PRACTICAL CONSTRAINTS ON THE IMPLEMENTATION OF THE IDEAL ENERGY CONSERVATION STRATEGY

This chapter examines each step in Figure 1 to determine how difficult each one is to accomplish and to assess a facility's current ability to complete it.

## Data Collection and Analysis

The first step (block B1) is to compile a list of buildings and other energy users. Such lists are usually already available on post. In fact, the IFS database provides easy access to a computer listing of a post's buildings, along with useful data, such as gross floor area, category code and year built. However, depending on the post, a substantial one-time effort may be needed to be sure the data is correct and up to date.

A certain amount of judgment is required to establish the expected building energy use (block B2), since the number must be a realistic target and is not necessarily equivalent to a design energy budget or actual measured use. A design budget can be unrealistic if (1) the building was not constructed as designed, (2) building use patterns are different from those used to compute the design budget, or (3) the building has significant process energy use (process energy use is often excluded from design energy budgets but must be included in establishing expected building energy uses). Measured data can also lead to unrealistic targets since it may cover inefficiently operated buildings.

Computer simulation of "typical" buildings has been used effectively in several EEAP studies to estimate expected energy use. This is a particularly useful approach because it can be the basis for later studies of conservation alternatives which could reduce expected energy use and because simulation results can be used to help identify possible causes of excessive energy use.

Another source of data is the report Fixed Facility Energy Consumption Investigation--Data Analysis,[5] which gives normalized measured data for many different types of buildings. Good "first cut" expected energy use estimates can be obtained from this data by using the measured data from buildings showing lower than average energy use.

For family housing, the equations presented in the report Family Housing Metering Test[6] are adequate for estimating expected energy use. They give estimates which are below the average of measured data but not below the measured use by energy-conscious occupants.

[5] Sliwinski, L. Windingland, D. J. Leverenz, and A. Mech, Fixed Facility Energy Consumption Investigation--Data Analysis, Technical Report E-143/ADA066513 (CERL, 1979).

[6] Family Housing Metering Test, Report to Congress, prepared by Office of the Deputy Assistant Secretary of Defense (March 1980).

Work is also underway at CERL to develop methods for estimating industrial process energy consumption. Block B3 (determining actual building energy use), poses a substantial problem. On most installations, very little metered data is available. However, individual areas are sometimes metered (for example, a block of family housing units). This provides at least a first estimate of what the actual building energy use patterns are. Fuel delivery data and data on the fuel consumption of central boiler or chiller plants can also be used to estimate building energy use, even though the data often do not correspond with a single, specific building or process. Existing data and meters need to be used more effectively, but more metering and data collection are required.

Block B4 (periodically compare actual to expected energy use) is not a problem if the appropriate data are known. However, since there are many buildings and many installations, and since comparisons should probably be made monthly to identify poorly performing buildings or processes quickly, this task could become tedious and time-consuming unless streamlined or automated procedures are developed.

Block B5 is simply a decision point. To complete this task, the list of buildings or processes should be screened and divided into two parts: (1) buildings or processes which require management or maintenance action, and (2) buildings or processes which should be considered for retrofit.

## Management and Maintenance

If a building or process is using more energy than expected (Block B5), the next procedure is to determine what action to take.

The first step is inspecting or auditing the facility (block M1). Here, the major problem is the lack of sufficient resources. Only a small sample of buildings have been audited as part of the EEAP studies.

An audit is done to answer the question posed in Block M2 or those posed in Block M4. In M2, we want to verify whether the estimate of expected energy use is correct. The inspection/audit of the building should reveal any changes in mission or building remodeling which might make the original estimate of expected energy use unrealistic. If the original estimate is wrong, then the expected energy use must be revised based on the building audit, and the process must be repeated beginning with step B4. Otherwise, we must try to identify the reasons for excessive energy use. Here again, personnel may not be available to do the work; however, unless specific reasons are identified, further action (M5 and M6) cannot proceed.

In M5, it is suggested that the building, its energy system, or the housed process be repaired if deficiencies are identified. If no deficiencies are found, then the habits of the occupants might be altered through education or through command emphasis on energy conservation, as suggested in block M6.

## Retrofit

Examining the retrofit path, it can be seen that Block R1 calls for determining appropriate retrofit technology to reduce expected energy use. This task, as well as the whole retrofit project development task, is often done by engineers hired to do EEAP studies. Therefore, the FE (or FE staff) often does not directly examine the technologies. However, regardless of who analyzes and selects the technology, the problem can be difficult because of the wide range of options available.

Other problems may arise if an unnecessarily complicated technology is recommended. For example, while an enthalpy economy cycle on an HVAC system can save energy, it is probably impractical due to the lack of satisfactory humidity-sensing devices needed to implement such a system reliably. Also, review of several post-wide studies shows that Energy Monitoring and Control Systems (EMCS) are frequently applied to serve primarily as time switches (clocks). While an EMCS can certainly save energy when used for this purpose, it may be much more complicated than other electronic time switches.

The FE does not seem to have effective, systematic methods for finding out about new technologies and for separating appropriate technologies from those which are too complicated or unreliable. More coordination between project development (e.g., Districts, architect-engineers doing post-wide energy studies) and the FE staff is needed to select appropriate technologies for retrofit projects. An appropriate technology must be simple and reliable to achieve expected energy use reduction and allow the maintenance staff to keep the building in good operating condition.

Block R2 requires that the retrofit project cost be estimated. Although this should be straightforward, the capital costs of energy conservation projects seem to be chronically underestimated. Part of the problem may be the use of realistically low cost-escalation factors. Another problem may be that projects tend to increase in scope between initial planning and final design.

The accuracy of expected energy and cost savings estimates (block R3) often depends on the project's complexity. For example, the expected savings of a relamping project can be estimated by simple tabulation. Procedures for estimating energy and cost savings for some common conservation schemes are outlined in the standard EEAP scope of work. However, for many building, process, and HVAC system renovation projects, estimating energy and cost savings is time-consuming, difficult, and prone to error. Computer simulation is often required to obtain accuracy.

Once appropriate retrofit technologies have been defined and their cost and energy savings estimated, block R4 indicates that it must be decided whether prospective projects are economical. Since fuel prices will change and the cost of certain conservation options decrease, block R5 suggests that projects that seem uneconomical now should be reconsidered periodically by the FE or industrial plant staff.

When block R4 is completed for all buildings and processes, a prioritized list and an installation master plan for retrofit can be developed.

If a building can be retrofitted economically, the planner must identify the appropriate source of funds (block R6). Energy conservation projects have usually used ECIP or ECAM money; however, there are other sources of funds. For example, OMA funds might be used for low-cost/high-return projects.

Block R7 calls for preparation of programming documents. This is a fairly straightforward task, and there is adequate documentation on the subject. Problems occurring in the document preparation phase usually result from lack of attention to detail during an EEAP study. These problems could be and often are resolved by closer communication between the architect-engineer performing the study and the FE staff and/or the District monitoring the EEAP contract.

Program documents must be approved (Block R8) by the MACOM, OCE, and often the Department of Defense. Approval can be delayed at the MACOM or OCE level if many projects are "in the pipeline" at one time. (This often occurs as fiscal year programming deadlines approach.) Because some past ECIP projects have been poorly prepared, MACOMs and OCE may review them more thoroughly than ordinary MCA projects.

Block R10 designates the action to design, award, and construct retrofit projects. Here, a major area of concern is assigning responsibility. Sometimes, projects are large enough or complex enough to be assigned to a District Office. However, the FE staff may be more able to determine exactly what course retrofit projects should take and better able to monitor the daily performance of the construction contract. The FE's interests should be emphasized when considering who is best qualified to carry out the design, award, and construction of retrofit projects, because the FE must "live with the project." Thus, the FE should be given every opportunity to design, award, and monitor a retrofit project if the FE office has adequate staff to do so. This approach could speed the completion of a project and reduce its design and contract adminstration costs.

Block R11 calls for defining a new value for expected building energy use, given that the retrofit project is complete. Problems associated with step R11 are the same as those given in block R3.

From Block R11, the path returns to the critical comparison step (Block B4).

# 5 COSTS AND BENEFITS OF A BUILDING ENERGY CONSERVATION STRATEGY

Of the three parts of the building energy conservation strategy previously described (data collection and analysis, retrofit, and management and maintenance), cost/benefit data are available for retrofit ECIP projects. Figure 2 shows the cumulative cost of projects and fuel cost avoidance achieved through FY80 on installations with ECIP projects.[7] The average E/C ratio for the ECIP was about 70 KBtu per year per dollar of capital cost. The average straight-line payback period for ECIP projects is 2.7 years. The authors of Army Energy Data Analysis conclude that, "Short of having 'before and after' metered data for validation of ECIP projects, this group comparison strongly indicates that ECIP projects are successfully reducing energy consumption in a cost-effective manner."

While some controversy remains concerning the validity of the data and conclusions about the effectiveness of ECIP, some savings are being achieved and actual E/C ratios and payback periods are probably of the order of magnitude of those given above. Before-and-after or side-by-side metering is still needed to assess the effectiveness of individual projects.

In contrast to the apparent effectiveness of ECIP, the relationship between the costs and the benefits of data collection and analysis, management, and maintenance remain to be determined. There are no data available on the amount of energy saved per year, either as a function of the number of buildings or processes with energy meters or as a function of the number of times actual energy use is compared to expected energy use; in addition, there are no data on the energy cost avoidance per dollar spent for building audits and minor energy-related repairs.

Isolated case studies suggest that there are benefits from the data collection and analysis and the management and maintenance phases. In one case, a timer in a dental clinic which was designed to shut off air-conditioning equipment at night was not working and probably caused the building to consume twice as much energy as expected. In another case, comparison of data from several wood-frame buildings constructed during World War II showed that one of the well-insulated buildings was consuming more energy than identical uninsulated buildings. An audit revealed that a broken window pane near the building thermostat was causing the heating system to run almost continuously. Occupants were opening windows during the winter to avoid overheating the building. Yet another case revealed excessive energy consumption in a modern Army barracks. Further analysis indicated that fan coil unit control deficiencies and poor performance of hot water temperature control systems were probably the cause.

While these cases are compelling, they are not adequate to indicate the costs and benefits of allocating the skilled resources needed for installing and reading more meters, tabulating and comparing data, auditing buildings, and carrying out energy-related maintenance and repair. The optimum staff or contract resource allocation for such activities is not yet known.

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[7] Army Energy Data Analysis (Department of Energy, July 1981).

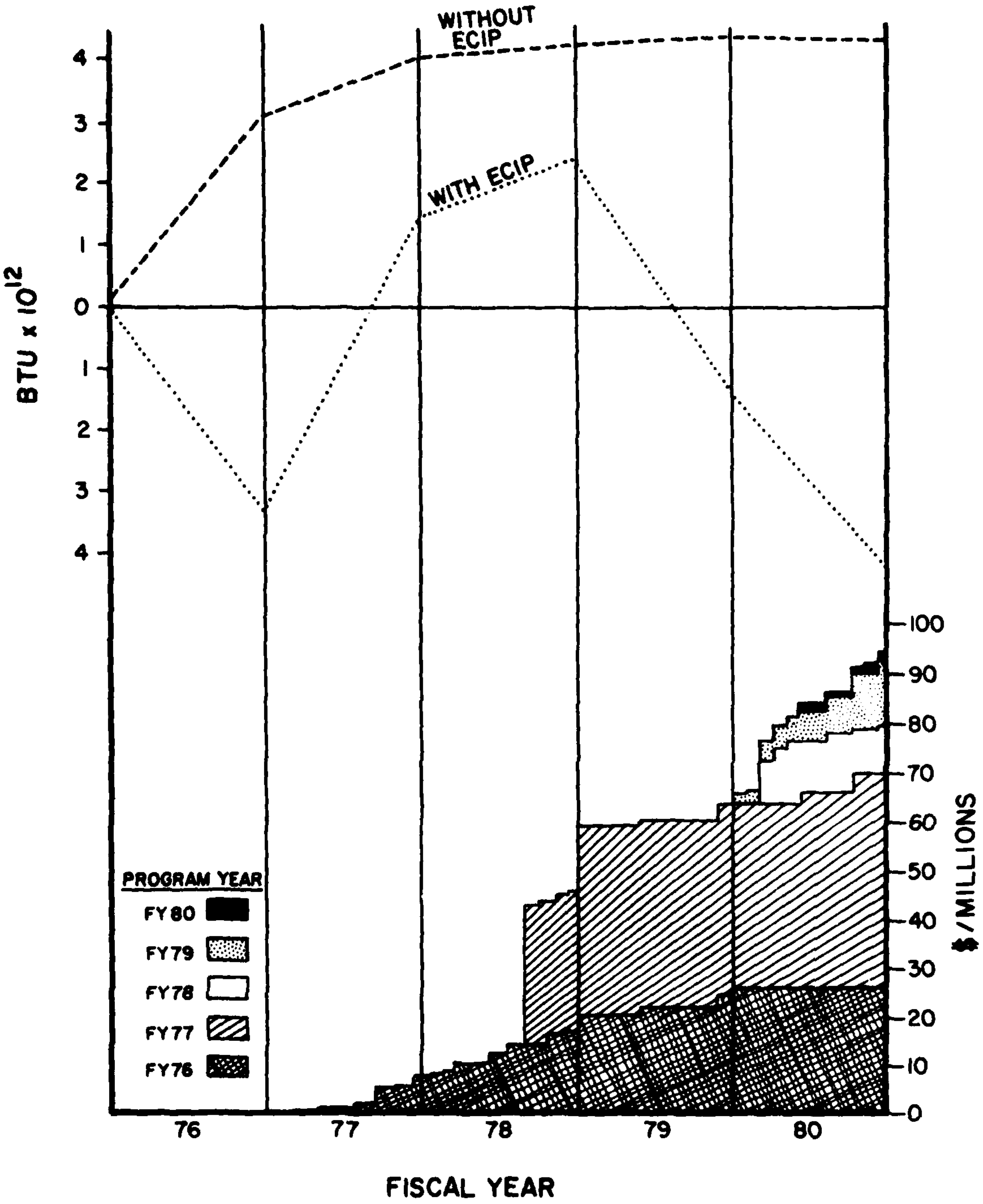


Figure 2. Cumulative cost of completed ECIP projects and annual change in energy consumption of installations with and without ECIP projects. (From Army Energy Data Analysis, Figure 4 [Department of Energy, July 1981].)

Fortunately, even though there is no cost/benefit information yet, data can be collected through carefully designed pilot-scale field experiments. ECIP can be justified on the basis of measured cost avoidance, but increases in resource allocations cannot be justified for metering, data analysis, auditing, and maintenance without first establishing estimates of potential cost avoidance. Planned field experiments should provide realistic estimates of the relationship between resource allocation and cost avoidance. In contrast, recall that cost avoidance for ECIP projects is usually estimated by standard calculation procedures, not field experiments.

In summary, data show that building retrofit projects are cost-effective and that estimated savings for these projects generally correspond to measured savings. Increased levels of effort and money for collecting and analyzing energy data and performing energy-related repairs would probably also be cost-effective. However, few data exist to show the expected savings of a given increase in resource allocation.

# 6 OTHER INSTALLATION-WIDE ENERGY CONSIDERATIONS

In addition to problems associated with conserving energy on a building-by-building basis, there are also installation-wide energy considerations.

One of these is the choice of centralized vs. decentralized heating plants. The use of large central plants serving many buildings increases the number of fuels which are economically appropriate. For example, a large heating plant can use coal or refuse as well as natural gas or oil. However, a substantial distribution loss penalty is characteristic of some large heating plants (particularly steam plants). Also, very high-efficiency (90 percent and higher) but small scale (up to 400,000 Btu/hr) gas- and oil-fired boilers and furnaces have been developed recently. Efficiencies for coal-burning equipment are not nearly as high. New, large-scale, high-efficiency boilers (particularly coal burning boilers) are not expected soon. Hence, the use of central plants precludes the use of this new high-efficiency boiler and furnace technology.

The central plant issue is tied to the conservation program for individual buildings and processes. For example, replacing a large oil-fired plant with a coal-fired plant might be economical, given <u>current</u> demands on the plant. However, if heating energy consumption can be reduced by, say, 30 percent in all the buildings and processes served by this central heating plant, then the scale of a coal-fired replacement plant might be reduced so much that coal conversion might no longer be economical. Conversely, building conservation projects may be economical if they save high-priced oil but not if they save less expensive coal.

The economics of building energy conservation, fuel selection, and the choice of centralized vs. decentralized utility systems are interrelated; these relationships must be considered in order to avoid conflicts between individual project objectives.

Another issue is the reluctance of post commanders to allow demolition of energy-inefficient older buildings, even after replacements for them have been built and are occupied. Two policies could alleviate this problem. The first is to enforce existing requirements for the scheduled demolition or "mothballing" of old (particularly World War I and World War II wood frame) buildings so that they are no longer energy consumers. The second is to recognize that if these buildings are not to be mothballed or demolished, they should be made energy-efficient through retrofit conservation projects.

An energy-related management concern is the allocation and control of technical and nontechnical resources. The task of developing and implementing a post-wide energy conservation strategy is one of the most complicated and demanding aspects of post operations. A characteristic of many successful energy management programs in large private and public institutions (i.e., large office buildings, airports, college campuses) is the existence of one highly qualified energy management engineer who is given a staff, an annual budget, the authority and responsibility for developing, prioritizing, and implementing energy conservation projects, the authority to determine how energy systems will be operated and controlled, <u>and</u> the full support of top level management. The performance of the energy management engineer and staff is

evaluated by comparing the measured energy and dollar savings achieved to targets set by the organization.

Elements of this type of energy management organizational structure exist in the Army (for example, the required creation of an Energy Management Office in AR 11-27). However, the required combination of authority, responsibility, money, staff, engineering skill, and top management support is not usually found at Army posts, even though there is little disagreement about the need for this combination if energy management is to be successful.

In the absence of metering, it is also difficult to evaluate the effectiveness of energy conservation and management responsibilities which are assigned to unit commanders or other installation personnel.

Another issue is whether EMCS can be used effectively to control individual building energy consumption and reduce installation energy costs. When properly applied, these computer-oriented systems can provide meaningful and useful feedback for both individual building and overall installation energy consumption and thus make building management and maintenance more effective.

However, EMCS have been plagued with design, construction, and operational problems. Many of the systems under contract are not now fully operational due to a wide range of technical, operational, training, contractual, and legal problems. To help overcome these problems, a technical team has been formed with a goal of making all systems currently under contract fully operational. Manufacturers involved in the contracts are also working to insure proper operation and timely completion.

Several actions have also been completed to improve future EMCS procurement including: publication of a new EMCS guide specification, publication of a technical design manual (TM 5-815), and the training of more than 100 Army engineers and 160 architect/engineer representatives involved in EMCS.

Other planned actions that will enhance future EMCS are: new training courses for EMCS construction inspectors and EMCS operators; additional DOD and OCE emphasis on EMCS; early interaction of EMCS users; and aggressive EMCS R&D programs. Even with the above efforts aimed at facilitating procurement and installation of EMCS, a strong local commitment is required if the potential benefits of EMCS are to be realized. The potential benefits of EMCS need to be carefully weighed against benefits achievable through other, less complicated energy conservation retrofit options.

Tampering and vandalism is yet another issue (for example, in troop housing, where room thermostat and fan-coil units are frequently damaged or destroyed). Lack of comfort probably motivates building occupants to try to change control settings on HVAC equipment. Discomfort can result from attempts to maintain low space temperatures in winter as an energy conservation measure or from poor design or performance of the HVAC system. Tampering and damage reduce the effectiveness of low thermostat settings. Furthermore, repairing damage and responding to frequent service calls requires manpower and money which might otherwise be spent on other energy conservation activities.

## 7 CONCLUSIONS AND RECOMMENDATIONS

This study has characterized "ideal" and actual procedures and processes used to implement energy conservation programs at Army installations and this report is intended to foster discussion and further analysis, debate, and information exchange. Results have been summarized in the following sections in a format that outlines a particular problem/need and then briefly recommends possible solutions.

In many cases, specific programs or work aimed at resolving problem/needs are planned or already underway. Where planned or ongoing R&D programs address problems/needs, they are indicated specifically. Review of the problems and needs described in this report by personnel involved in the installation energy conservation process (FEs, OCE, MACOMs) was accomplished at a project In-Process Review (IPR) held at CERL. Their input and suggestions are reflected in this summary and in the priorities set for future energy conservation research and development.

### Problem/Need

Existing procedures for estimating expected building and process energy use need to be improved (block B2 of Figure 1).

### Discussion

Existing simulation procedures should be simplified. Correlations based on measured data must be refined to exclude poorly operated buildings. Cross checks between simplified calculation procedures and measured data should be carried out and any differences should be reconciled. FE staff should be given training and guidance in energy use estimation procedures.

### Problem/Need

The amount of metering for actual building and process energy use is inadequate and prohibits effective management of energy use (block B3).

### Discussion

IPR participants viewed this problem as most important. Procedures should be developed to maximize use of available data. Techniques for developing low-cost metering plans for Army installations need to be developed. Minimum requirements for the amount of energy use data which should be collected (metered) need to be established. Low-cost meters should be developed, and the trade-off between accuracy and cost should be investigated. Meters (both thermal and electric) should be installed on all new buildings and during major repair or renovation of existing buildings.

## Problem/Need

The FE staff needs energy recordkeeping procedures to make effective use of estimated and measured energy use data (blocks B4 and B5).

## Discussion

If energy data is to be useful, managing it must not be burdensome, and data collection and reporting should be more than a paperwork exercise. The FE's needs (not the MACOM's, or OCE's) for recordkeeping and energy data management should be identified. Simple, yet flexible, microcomputer-based energy recordkeeping and analysis systems should be developed for optional use by FEs.

## Progress

Small-scale prototype schemes will be developed under the "Post-Wide Energy Conservation Demonstration" project scheduled to begin in the third quarter of FY83.

## Problem/Need

Resources must be identified for carrying out energy inspections or audits of buildings which use more energy than expected (block M1).

## Discussion

Buildings which use too much energy must typically be audited to identify the cause of excessive use. Under the EEAP program, only a fraction of an installation's buildings are to be audited and then only one time. These buildings may not be necessarily be those which use more energy than expected. Sources of in-house or contract resources need to be identified, funds budgeted, and procedures drafted so that audits can be carried out as required.

## Problem/Need

Procedures should be developed for sharing information about new retrofit technologies and for separating appropriate technologies from those which may require excessive maintenance or place excessive workloads on the FE staff (block R1).

## Discussion

Some retrofit technologies, particularly complicated HVAC control system modifications, require skilled and frequent maintenance to remain effective. If resources for maintenance are not available, the energy savings potential of the project will not be realized. Also, in some cases, much simpler projects which are relatively maintenance-free can achieve equal or nearly equal

energy savings. Training and information sharing might avoid inappropriate technologies.

## Progress

The project "Retrofit HVAC Controls for Energy Conservation," initiated in FY82, will investigate questions of complexity vs. maintainability and reliability. Verified schemes for energy-efficient HVAC control will be developed.

## Problem/Need

Procedures for estimating energy conservation project costs must be improved (block R2).

## Discussion

Estimates could be improved by sharing information; first-cost estimates for retrofit projects can be partially based on similar, recent projects, for which actual bid prices have been obtained. This information exchange should occur early in the preliminary cost-estimating process. More frequent updates of cost escalation factors should also be considered.

## Problem/Need

Estimating expected energy savings for retrofit projects can be time-consuming, difficult, and error-prone (block R3).

## Discussion

Two possible approaches could make this task less cumbersome and more reliable:

1. Maintain a database of "before" and "after" energy consumption figures for as many retrofit projects as possible.

2. Develop approved, simple "rule-of-thumb" methods for estimating expected energy and cost savings, particularly for the most common types of buildings on Army installations. Distribute this information widely.

## Progress

Retrofit "packages" for common types of existing buildings including energy savings estimates have been developed under the project "Retrofit Conservation Alternatives for Standard Army Buildings." Rule-of-thumb methods for energy savings estimates for simple conservation projects are now included in the EEAP scope of work.

Problem/Need

In addition to ECIP funding sources, other appropriations should be used more fully for energy-related projects (block R6).

Discussion

Additional guidance on the use of various funding sources for energy-related projects should be developed to bring attention to them. It may be desirable to have periodic meetings to discuss projects under different funding categories and set priorities for them within a command-wide plan.

Problem/Need

MACOM and OCE review of ECIP and other energy-related projects should be expedited (block R8).

Discussion

The review time for energy-related projects has decreased as engineers have become more experienced in preparing and reviewing them. However, a comprehensive tabulation of completed energy conservation project results would provide data useful for determining whether new projects are reasonable in terms of capital cost and expected energy savings.

Problem/Need

It may be desirable to delegate authority for design, award, and construction retrofit projects to the FE more frequently.

Discussion

It may be more efficient if the local FE staff supervises certain types of conservation projects (e.g., relamping, storm window, or insulation projects). To minimize the additional workload, aids such as short-form guide specifications, lists of approved products, cost data, and project documents for energy conservation projects from other installations should be made available to the FE.

Problem/Need

There is not enough data for FEs, MACOMs, OCE, and DOD to determine whether more effort and cost can be justified for the following energy-related activities (see Chapter 4):

1. Collection of energy consumption data (i.e., installing and reading more meters).

2. Setting realistic detailed targets (estimating expected energy use for buildings or groups of buildings).

3. Energy data analysis (comparing expected to actual energy use on a building-by-building basis).

4. Inspection of energy inefficient buildings (identifying causes of excessive energy use).

5. Carrying out energy-related maintenance (repairing buildings, systems, and controls).

6. Carrying out energy-related management (educating occupants, seeking command emphasis).

## Discussion

The relationship between the benefits and costs for various increased levels of energy data collection, data analysis, maintenance, and management should be determined through field experiments. Two major questions must be addressed:

1. Will more effort and cost result in significant energy and cost savings?

2. If significant savings are possible, how can the optimum level of effort be determined?

## Progress

The project "Post-Wide Energy Conservation Demonstration," planned to begin in third quarter of FY83 will thoroughly investigate methods for using available data effectively and for collecting additional energy consumption data at the lowest possible cost. The field studies will also require developing a prototype energy recordkeeping system so that otherwise tedious energy data analysis can be carried out quickly.

Results of the field studies will also help refine both the required number and the skill level of staff which should be assigned to energy conservation activities.

## Problem/Need

Building energy conservation programs, fuel selection policy, and use of centralized vs. decentralized heating plants are interrelated issues which should be considered simultaneously, not independently. Distribution losses also need to be quantified.

### Discussion

Army design guidance and fuel selection and energy distribution system policies should be re-evaluated. The following should be considered: emerging technologies; efficiency of existing centralized and decentralized systems; distribution line losses (these can often be measured easily; data should be collected from Army installations worldwide); potential limits of cost-effective conservation; and national energy conservation goals.

### Progress

This problem is being systematically addressed under the project "Installation Fuel Strategy Program Development" which began in FY82.

### Problem/Need

Many old woodframe buildings are still in use and often consume excessive amounts of energy.

### Discussion

Policies regarding the use or demolition of existing temporary woodframe buildings should be re-evaluated. Standard retrofit packages for these buildings should be developed.

### Problem/Need

EMCS has been applied with varying degrees of success, and many of the systems have had problems.

### Discussion/Progress

Research, application engineering, training, and project monitoring programs should continue until all major EMCS are functioning successfully.

### Problem/Need

Effective energy conservation programs require Command emphasis.

### Discussion

This is a policy issue rather than a research topic.

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